جامعة ابن زهر
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UNIVERSITÉ IBN ZOHR

Centre National pour la Recherche Scientifique et Technique

Laboratoire de Physique Théorique et Hautes Énergies

DARK MATTER EFFECT ON QPOs OF CHARGED PARTICLE AROUND BLACK HOLE

Presented by:

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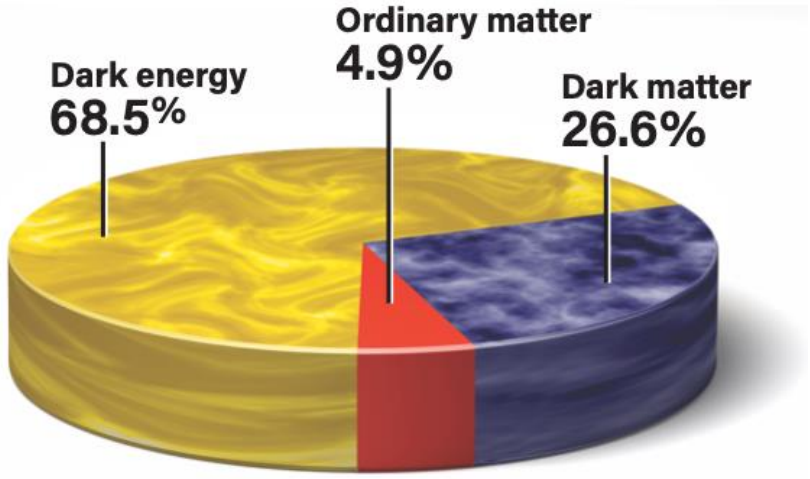
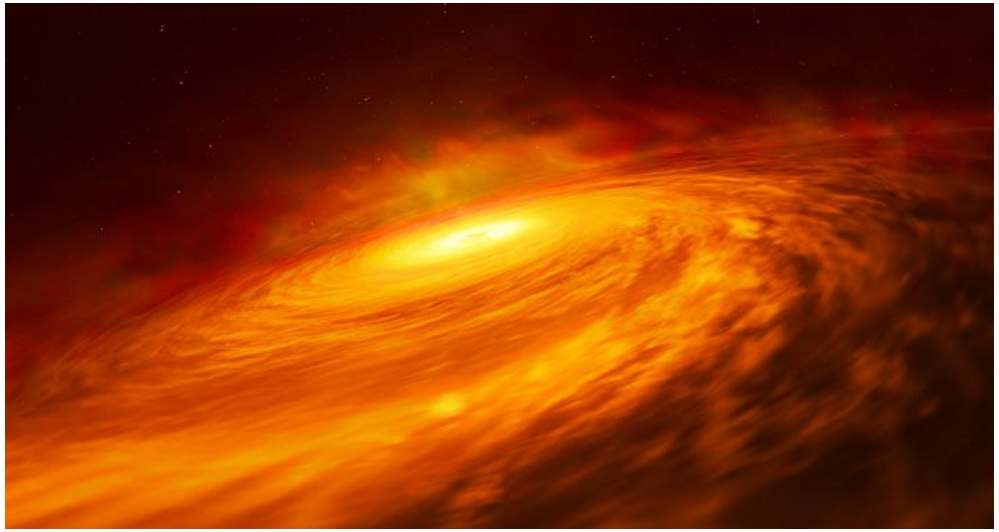
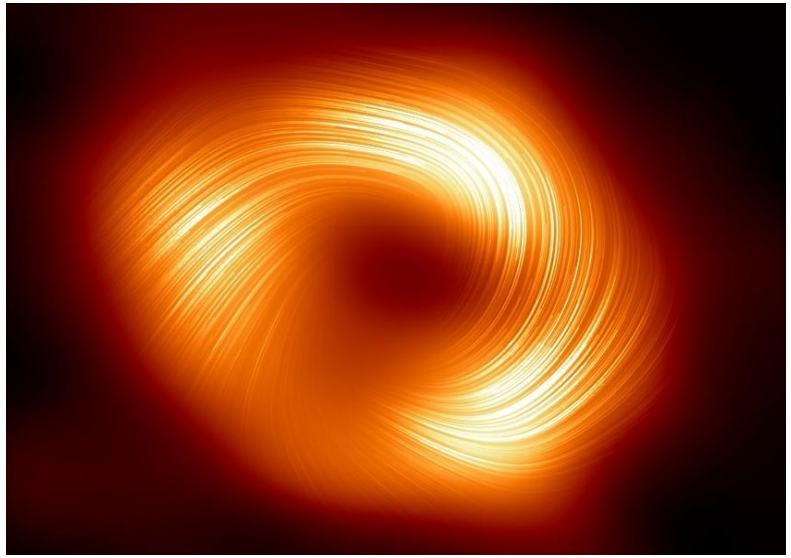
I'm Here, Latitude: 30.4167° N, Longitude: -9.6000° W.

INTRODCUTION

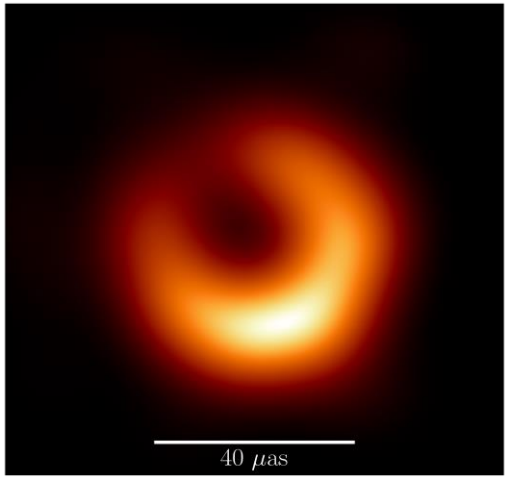




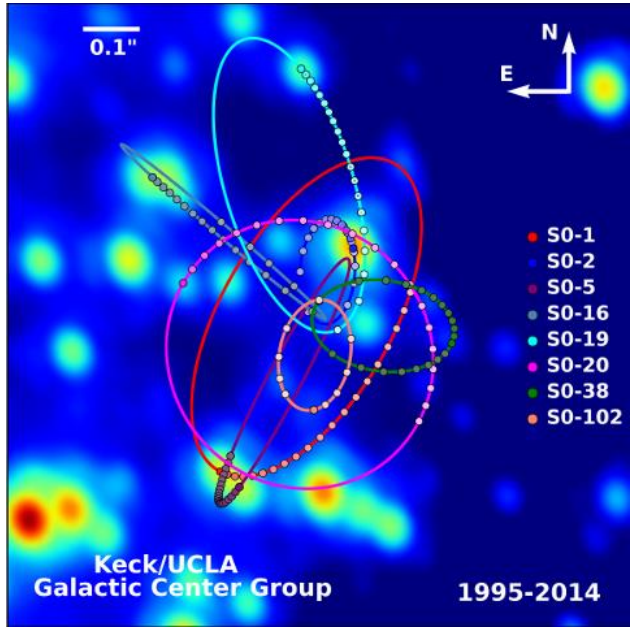
Accretion disc of BH



Event Horizon Telescope image of sgr A*



M87*



Cluster stars around sgr A*

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DARK MATTER EFFECT ON BLACK HOLE

Schwarzschild Black Hole

$$ds^2 = -\left(1 - \frac{2}{r}\right)dt^2 + \left(1 - \frac{2}{r}\right)^{-1} dr^2 + r^2 d\theta^2 + r^2 \sin(\theta)^2 \; d\phi^2.$$

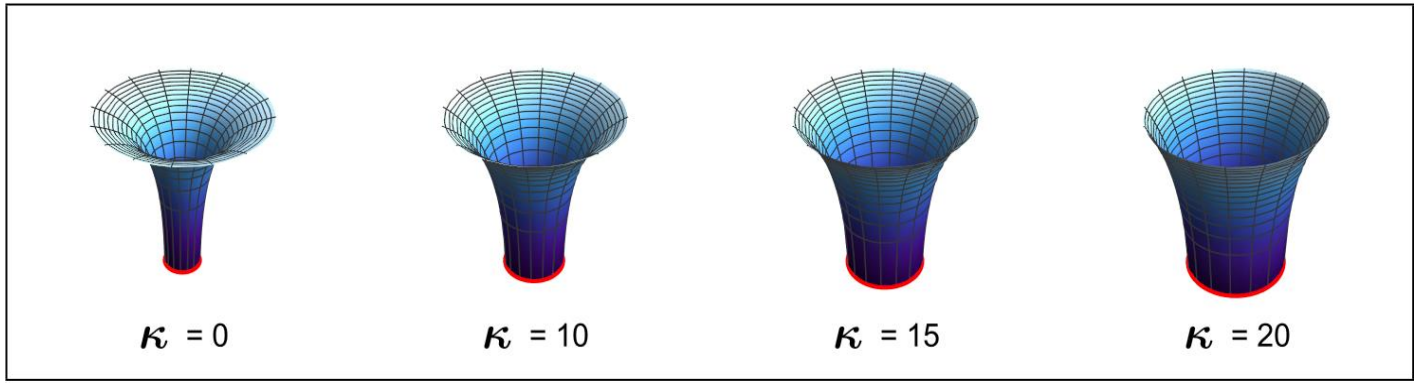
CDM + *Schwarzschild Black Hole*

$$ds^2 = -\left(\left(1 + \frac{r}{R_S}\right)^{-\frac{8\pi\kappa}{r}} - \frac{2}{r}\right)dt^2 + \left(\left(1 + \frac{r}{R_S}\right)^{-\frac{8\pi\kappa}{r}} - \frac{2}{r}\right)^{-1} dr^2 + r^2 d\theta^2 + r^2 \sin(\theta)^2 \; d\phi^2.$$

$\kappa = \rho_s R_s^3$,

ρ_s : The characteristic (core) density,

R_s : The charactestic radius.



- *JCAP 2018*(09), 038.

DARK MATTER EFFECT ON CHARGED PARTICLE

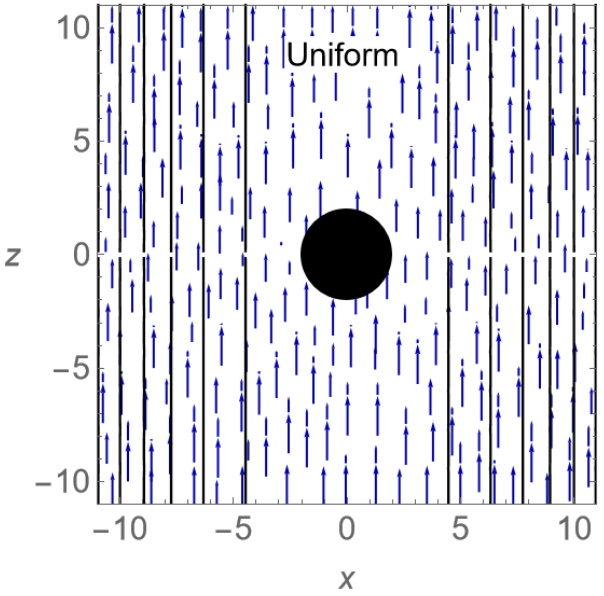
Gravity + CDM (Cold DM)+ Magnetic field (Uniform magnetic field)

Hamiltonian *:* $$H = \frac{1}{2} g^{\alpha\beta} (\pi_\alpha - qA_\alpha)(\pi_\beta - qA_\beta) + \frac{1}{2} m^2$$

- Effective potential V_{eff}
- Equation of motion

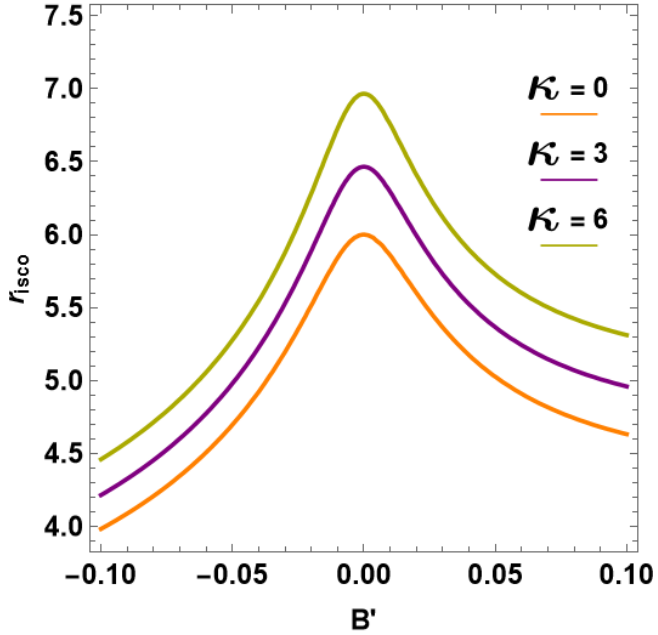
canonical four-momentum

Four-vector potential



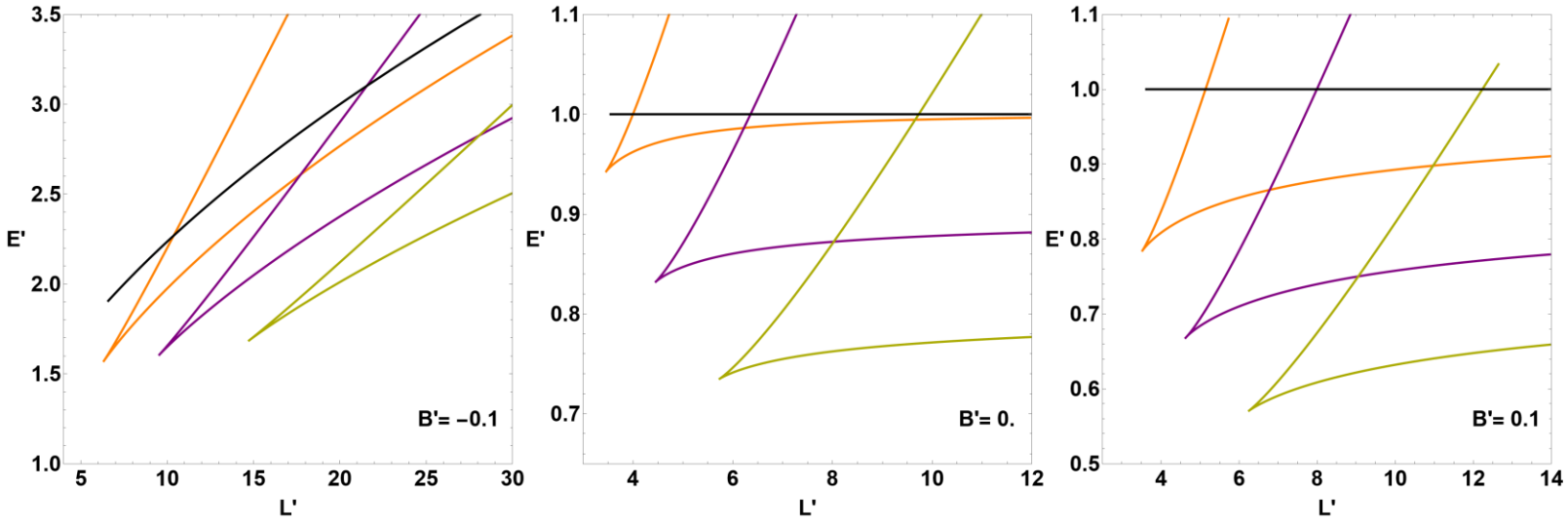
DARK MATTER EFFECT ON CHARGED PARTICLE

- **Specific angular momentum** : $L' = p_\phi = g_{\phi\phi}\,(\dot{\phi} + B')$
- **Specific energy** : $E' = -p_t = g_{tt}\dot{t}$
- Minima of the V_{eff} refers to the stable circular orbit of particle.
- ISCO exist in the inner edge of the accretion disc.



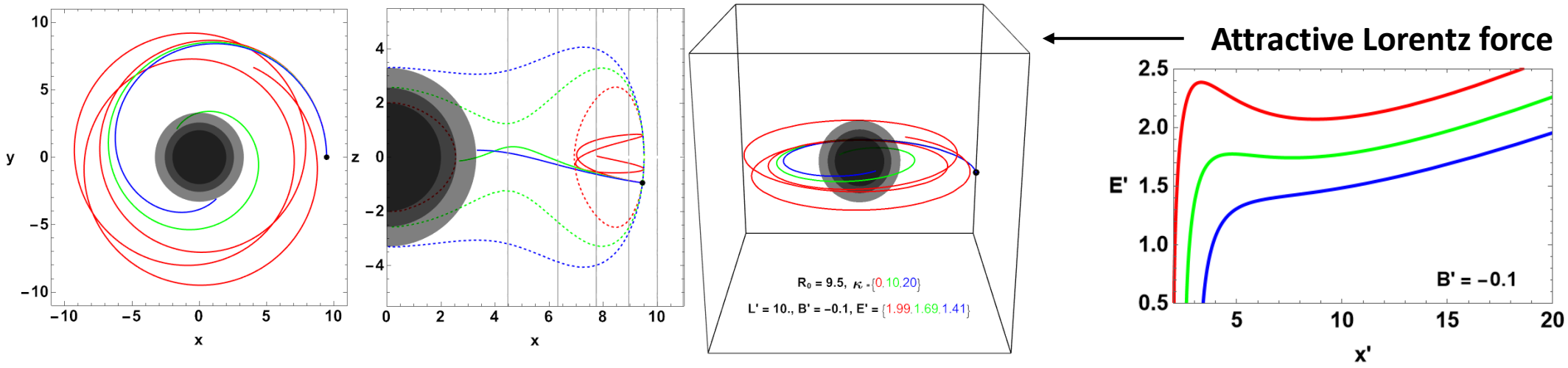
ISCO radius variation

Innermost **S**table **C**ircular **O**rbit

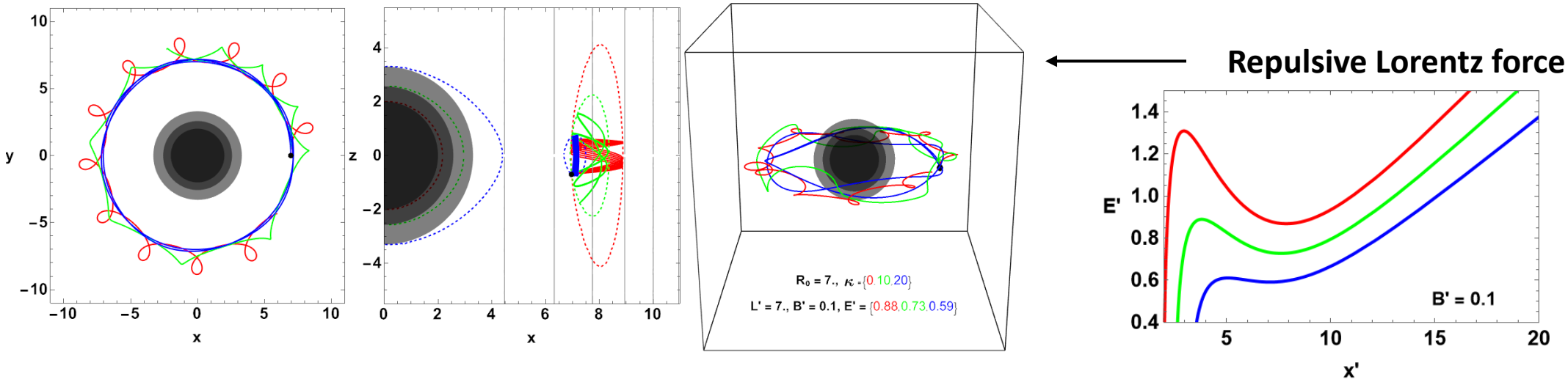


Specific Energy on function of angular momentum $\kappa = \{0, 10, 20\}$

DARK MATTER EFFECT ON CHARGED PARTICLE



- As κ increases, the orbits become more confined and trapped toward BH.
- The transition from open to closed energy surfaces as $\boldsymbol{\kappa}$ grows.
- CDM significantly perturbs the coordinate of the ISCO.



DARK MATTER EFFECT ON QPOs

- Quasi-Periodic Oscillations (**QPOs**) observed in Microquasars .
- **Microquasars** : Binary system consist of BH or neutron stars, A surrounding accretion disk emiting X-rays.
- High Frequency QPOs (**HF QPOs**) detected as **twin peak** in the power spectral density appear as 3:2 frequency ratio.

- **Epicyclic Resonance (ER)** : Result of non-linear resonances between radial and vertical epicyclic oscillations of matter in the inner regions of the accretion disk.
- **Relativistic Precession (RP)** : Attributes QPOs to relativistic corrections in particle orbits near the BH.
- **Warped Disk (WD)** : Addresses QPO generation in geometrically warped accretion disks.
- **Tidal Disruption (TD)** : HF QPOs as resulting from the tidal disruption in the accretion disc by gravitational field of BH.

	GRS 1915+105	H1743-322	XTE 1550-564	GRO 1655-40
$M\ [M_\odot]$	$9.6 - 18.4$	$9.25 - 12.86$	$8.5 - 9.7$	$6.03 - 6.57$
ν_U [Hz]	$165 - 171$	$237 - 243$	$273 - 279$	$447 - 453$
ν_L [Hz]	$108 - 118$	$158 - 174$	$179 - 189$	$295 - 305$

- *ARAA.*, *44*(1), 49-92.
- *MNRAS*, *444*(3), 2065-2070.

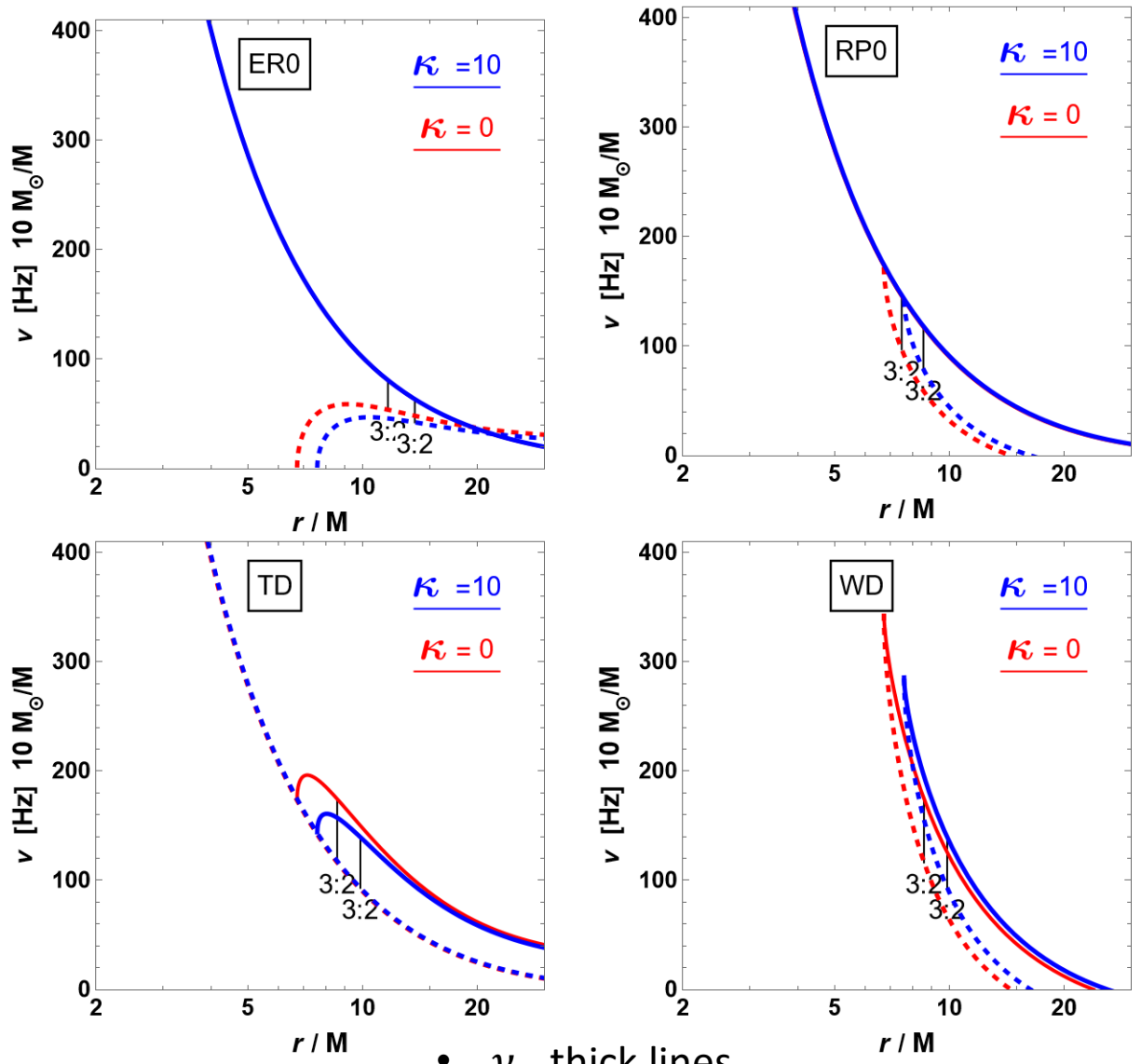
DARK MATTER EFFECT ON QPOs

- Perturbing a particle at the minimum of $V_{eff}(r,\theta)$ leads to oscillations
- Frequencies as measured by distant observers located at spatial infinity

$$\nu_i = \frac{c^3}{2\pi GM}\frac{\omega_i}{-g^{tt}\,E'}$$

- $\omega_r^2 = \dfrac{\partial^2 V_{eff}}{\partial r^2}$
- $\omega_\theta^2 = \dfrac{1}{rf(r)}\dfrac{\partial^2 V_{eff}}{\partial \theta^2}$
- $\omega_\phi = \dfrac{d\phi}{d\tau}$

- **ER0** : $\nu_U = \nu_\theta\ ,\ \nu_L = \nu_r.$
- **RP0** : $\nu_U = \nu_\phi\ ,\ \nu_L = \nu_\phi - \nu_r.$
- **TD** : $\nu_U = \nu_\phi + \nu_r,\ \nu_L = \nu_\phi.$
- **WD** : $\nu_U = 2\nu_\phi - \nu_r,\ \ \nu_L = 2(\nu_\phi - \nu_r).$



- ν_U thick lines
- ν_L dashed lines

- *EPJC*, *81*(12), 1067.

CONCLUSION

- CDM influences the BH geometry by affecting the radius of the event horizon.
- The location of the ISCO varies depending on the B′ strength and CDM density- $\boldsymbol{\kappa}$.
- The CDM reduce the specific energy of particles
- The presence of the CDM shifts the resonance radii away from the BH in all considered models.


Thank You
For Your
Attention